

REGIONAL SEDIMENT MANAGEMENT: A GIS APPROACH TO SPATIAL DATA ANALYSIS

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ABSTRACT: Regional sediment management (RSM) requires the capability for stakeholders in management decisions to explore the broad spatial and temporal impacts of potential management actions. In the U.S. Army Corps of Engineers coastal RSM Demonstration Program several tools have emerged as necessary components for effective planning in regional sediment management. A geographic information system with specialized applications was developed to provide baseline information for regions including hydrographic and topographic data, shoreline position, aerial and oblique photography, dredging records, nautical charts, and other data regarding regional utilities, infrastructure, and land use. Customized GIS applications were developed to retrieve pertinent hydrologic information, to extract dredging information from district databases via reporting tools, and to create bathymetric profiles and volume changes. The GIS also incorporated existing technology in regards to numerical models.

KEYWORDS: GIS; data analysis; bathymetry; aerial photography; profiling; volume calculations.

INTRODUCTION

The Spatial Data Branch, Operations Division, USACE Mobile District, created a Geographic Information System (GIS) to address the data management and data analysis requirements of the Regional Sediment Management (RSM) Demonstration Program undertaken by USACE Mobile District. The resulting GIS provides RSM scientists and engineers an interface to hydrographic, topographic, photogrammetric, and historic dredge material data for the RSM Demonstration Region, as well as custom applications designed to facilitate engineering analyses. The RSM GIS serves as the link between engineering analyses and regional numerical models. To date, development of the RSM GIS has included: input of spatial data for the RSM region, use of built-in ArcView applications to enhance data manipulation and display, and creation of custom applications to extend the utility of ArcView for RSM specific goals. This paper will give an overview of the effort to create the RSM GIS including data preparation for inclusion in the GIS, data display using ArcView, creation of custom applications for RSM, and other capabilities currently under development.

Spatial Data Input

Spatial data that are currently included in the RSM GIS include: hydrographic and topographic survey data, aerial and oblique photography, dredge material records, digital nautical charts and USGS quad sheets, environmental data, and generic GIS information. Each of the datasets listed above were converted to the same horizontal and vertical datums. The RSM GIS is in geographic coordinates (latitude/longitude) with the North American Datum 1983 (NAD83) as the horizontal datum and the North American Vertical Datum 1988 (NAVD88) as the vertical datum.

Hydrographic and Topographic Survey Data

Hydrographic and topographic survey data are required for the RSM Demonstration Program in two forms. First, a unique data set must be created for each survey collected in the region. Second, the datasets must be merged into a single most recent, or “baseline” data set that covers the entire region. The RSM GIS datasets include three types of hydrographic and topographic data: singlebeam fathometer data, multibeam fathometer data, and airborne LIDAR bathymetry and topography.

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Aerial and Oblique Photography

Both aerial and oblique photos are included in the RSM GIS. All historic aerial photography currently included in the RSM GIS was provided by various sources and were of various geographic projections. All aerial photographs were either ortho-rectified or reprojected, mosaicked, and finally compressed using Multiresolution Seamless Image Database (MrSID) software. During the first year of this project, images were processed using the Image Analysis extension of ArcView. Later, all processing was completed within ERDAS Imagine.

Oblique photos, along with their corresponding descriptions, were provided to the Spatial Data Branch in hardcopy form. The photos were scanned, cropped, and saved in a GIF file format. Photo descriptions were typed and saved as text files. Through the Historical Photos application inside the RSM GIS, oblique photos are viewed and can be printed with the corresponding descriptive data.

Dredged Material Records

Historical dredged material records are stored in a customized database. The database stores information regarding dredging history for each of the nine federal navigation projects in the region. Every known dredging event is included in the RSM GIS dredge material database, along with associated removal sites, dredge material quantities, placement sites, dredge contractors, and costs associated with the dredging contract. This information was collected from the USACE Mobile District Operations Division's Irvington and Panama City Site Offices.

Digital Nautical Charts and Quad Sheets

NOAA nautical charts serve as the hydrographic background for all other graphic entities built into the coastal areas within the RSM GIS. These nautical charts were obtained from MapTech distributed CD's. USGS quad sheets serve as the topographic background.

Generic GIS Data

GIS data such as streets, political boundaries, landmarks and water features are provided to the USACE Mobile District by Dynamap/2000®. The database is built on a county by county basis and identifies more than 30 types of landmarks organized in logical themed layers, including railroads, airports, parks, recreational areas, transportation terminals, and institutions (such as schools and hospitals). These data are released in GIS format and are directly importable into the RSM GIS, provided that they are in the proper projection.

Data Manipulation and Display Using ArcView

ArcView and its extensions provide a great deal of data manipulation capability. This section outlines the use of built-in ArcView functionality for the creation of new coastal entities like the mean high water line and bathymetric contours.

Shorelines

Shorelines were created directly in ArcView. The shoreline was determined from the position of the debris line on the ortho-rectified aerial photographs. The debris line often denotes the location of mean high water (MHW), which is the desired shoreline for most coastal applications. The shoreline was delineated using heads-up digitizing in ArcView. The position of the debris line on the ortho-rectified aerial photographs were marked approximately every 50 feet. Through the X tools extension in ArcView, a linear interpolation was performed between each point to create the MHW shoreline.

Triangulated Irregular Network

Using the ArcView 3D Analyst extension, a triangulated irregular network (TIN) was created from each of the hydrographic and topographic datasets included in the RSM GIS. TINs allow RSM data users to use these datasets as surfaces, rather than as two-dimensional data points with an elevation attribute. The surfaces allow for more accurate volume computations between data layers and are included as a data layer in the GIS.

Grids

3D Analyst was also used to create a grid of each data set. A grid is a set of regularly spaced data points created from a set of irregularly spaced data points, like the topographic and hydrographic datasets. In the RSM GIS, grids were created from TINs in order to most accurately represent elevation changes about the surface. Grids are used to facilitate calculations

between datasets and volume computations. At each XY grid point an elevation is interpolated based on the elevation of the TIN at that same XY grid point. Each grid has been assigned a color scale based on elevation of the grid points. This colorizing of the grid points has the effect of creating color-filled contours for each data set. The grids are included as a data layer in the GIS.

Contours

Linear contours are also included as a layer in the RSM GIS. The contours were created using 3D Analyst. The contours are spaced at 5 foot intervals. The contours are drawn based on the elevations given by the grid surfaces.

Custom Applications for ArcView

Several custom applications have been written to extend the capability of ArcView to meet RSM specific goals. These applications are generally written in AVENUE script and Visual Basic and take advantage of ArcView and ArcView extension functionality. AVENUE is ESRI's programming language.

Oblique Photo Tool

Aerial and oblique photography often contains valuable qualitative information regarding the condition of beaches, dunes, offshore shoals, and other coastal features. Oblique photography, generally taken with a standard camera from the beach itself, from nearshore buildings, or sometimes from the air, cannot be integrated into a GIS because it lacks positioning information. Conventional aerial photography can be integrated with a GIS if necessary rectification information and camera reports are available. However, especially with older aerial photography, often the only information available is the contact print itself.

To include these valuable photos in the GIS, even though no positioning information is available, an oblique photo tool was created that hotlinks these photos to the areas in which they were taken. For example, several photos have been collected at East Pass, Florida, that cannot be rectified for input into the GIS. The oblique photo tool allows the RSM GIS user to select a location and view available photography displayed with any relevant information. An example of the oblique photo tool is shown in Figure 1.

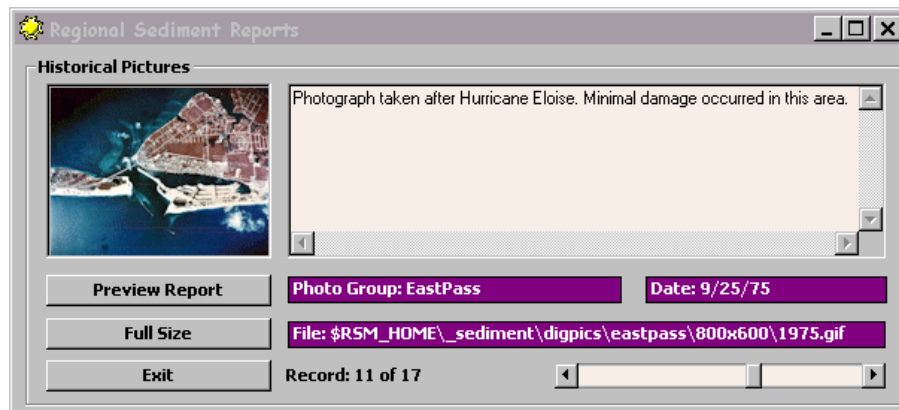


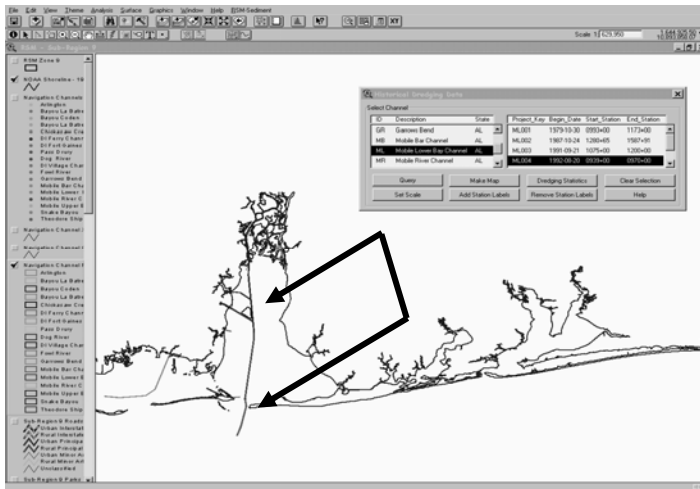
Figure 1. Custom oblique photo viewing tool built for the RSM GIS. The left side of the dialog shows a thumbnail view of a photo taken at East Pass, Florida, while the right side contains the photo location, date, and a caption stored for the photo.

Dredge Data Reporting Tool

The dredge material database is accessed through the dredge data reporting tool. The reporting tool calls up all known dredging events from the dredge material database. The user may access a *Dredging Report* by selecting an event from the scroll down list. The user may also select a particular navigation channel from the spatial domain of the RSM GIS and view reports for every event within that particular channel.

An example of a dredge data report is shown in Figure 2. Figure 2a shows the spatial domain of the RSM GIS near Mobile Pass, Alabama. Visible in the domain are the shoreline and navigation channels in this area. The dredging event highlighted in the dredge data reporting tool (shown blacked out here) is linked to the channel section highlighted in the main window of Figure 2a (denoted by arrows here). The dredge data reporting tool then uses data extracted from the dredge material database to fill a dredging report. A portion of a dredging report is shown in Figure 2b.

(2a)



(2b)

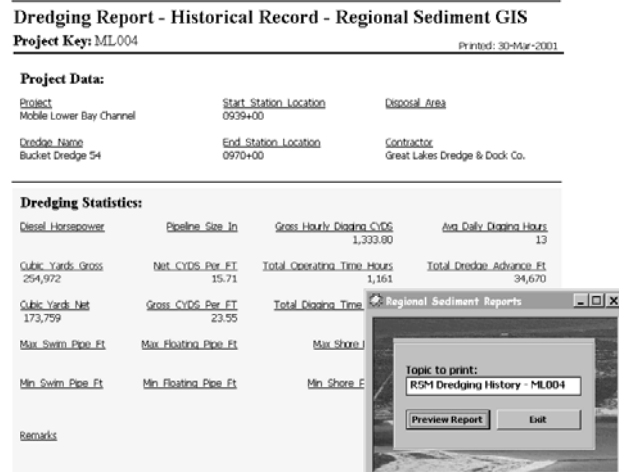
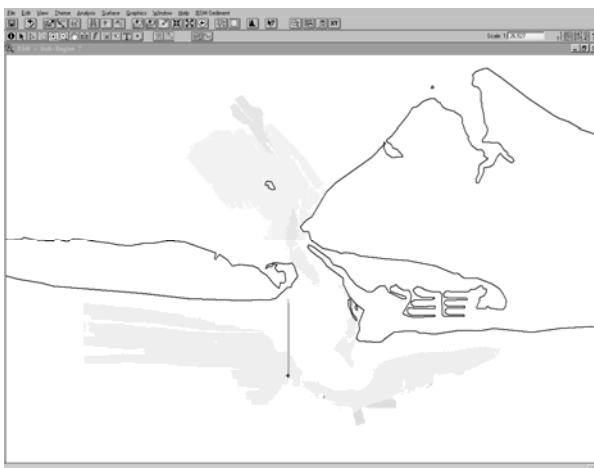


Figure 2a and 2b. Dredging Report tool created for RSM GIS. Figure 2a shows the RSM GIS spatial domain near Mobile Pass, Alabama. This view includes the shoreline and navigation channels in this area. Figure 2b shows a portion of the dredging report filled with data from the dredge material database.

Profile Tool

Beach profiles have been collected as part of the coastal monitoring for the State of Florida for many years. Part of the baselining effort for the RSM Demonstration Program included the collection of beach profiles along the entire coast of Alabama. To compare this data with higher-density datasets, like SHOALS or multibeam datasets, users must be able to view profiles extracted from the higher density datasets at locations where historical profiles were collected. The profile tool allows the user to extract profiles from the higher density datasets. The profiles may be extracted along hand drawn line objects. The profile tool creates a set of elevations along a line based on the grid surfaces included in the GIS. An example profile tool is shown in Figure 3. Figure 3a shows the spatial domain of the RSM GIS near East Pass, Florida. Visible in the domain are the shoreline in this area, the grid surface for a SHOALS data set collected in at East Pass in 1996, and a solid line for which a profile will be extracted. Figure 3b shows the profile viewing window, where a profile is shown for both the November 1995 SHOALS data set and the 1996 SHOALS data set.

(3a)



(3b)

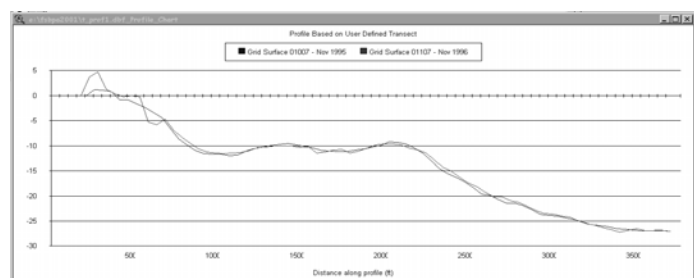


Figure 3. Profile tool created for RSM GIS. Figure 3a shows the spatial domain of the RSM GIS near East Pass, Florida. This view includes the shoreline in this area, the grid created for the 1996 SHOALS data set, and a line where a profile is desired. Figure 3b shows the profile viewing window, where a profile is displayed for the November 1995 SHOALS survey and the 1996 SHOALS survey.

Compute Volumes Tool

The compute volumes tool gives RSM engineers and scientists the capability to compute volumes between datasets. The volumes are computed based on the grids created from the original datasets. The user may compute a volume by drawing an area (polygon) for which a volume is desired. At each grid point, an elevation difference is calculated between the two datasets. The volume is determined by integrating the differences over the areas they represent. The volume for the designated area is reported in a pop-up window. The differences are stored as a data layer in the RSM GIS.

An example showing the computed differences is shown in Figure 4. This view shows the spatial domain for the RSM GIS near East Pass, Florida. Visible in the domain are the shoreline and the difference grid computed during a volume calculation. The difference grid is shown in the lower central portion of the view. The black and dark gray grid cells are areas of positive difference, or accretion. The lighter gray areas are areas of negative difference, or erosion.

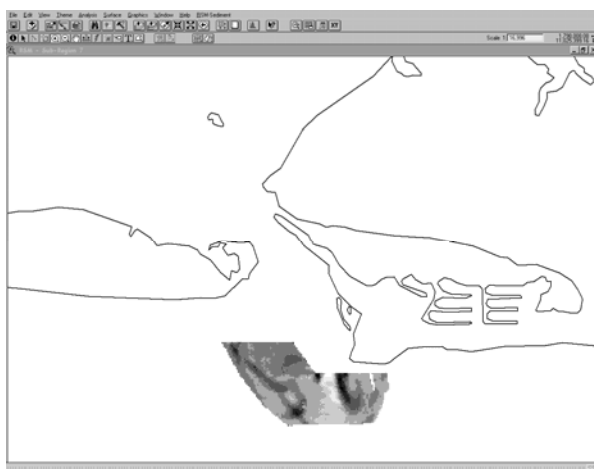


Figure 4. Volume tool created for RSM GIS. This figure shows the spatial domain for the RSM GIS near East Pass, Florida. The view includes the shoreline and the difference grid computed during a volume calculation. The black and dark gray grid cells are areas of positive difference, or accretion. The lighter gray grid cells are areas of negative difference, or erosion.

Additional RSM Tools

Six additional tools created specifically for the RSM are the RSM theme tool, a dynamic search tool, a coordinate conversion tool, two printing tools and the theme documents tool. The theme tool allows users to select a group of themes, or data layers, to add to a view at a single time. For instance, all the themes in the area surrounding East Pass, Florida may be added as a single group. The dynamic search tool allows the user to search for a specific feature within a single theme. The coordinate conversion tool allows the user to convert between UTM and geographic coordinates. The printing tools allow the user to automatically print the current view or select feature attributes to output to the printer. Any data layer can have an associated array of non-spatial data (Excel Spreadsheets, PowerPoint Presentations, PDFs, websites, etc.). These documents can be viewed in the GIS when the Theme Documents tool is used, as seen in Figure 5.

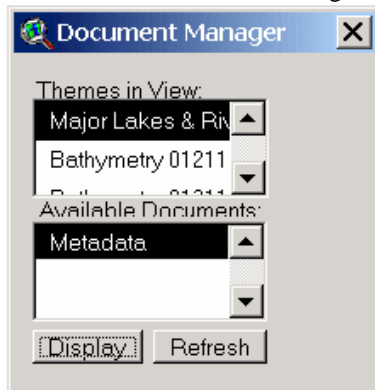


Figure 5. Non-spatially referenced data can be selected in the Theme Documents tool.

Two additional applications have been incorporated to aid in the analysis of coastal data. With the Beach Fill application, users can build a hypothetical area of beach placement to analyze different beach fill scenarios. The Sediment Budget application allows users to create and balance littoral cells within their area of interest as depicted in Figure 6.

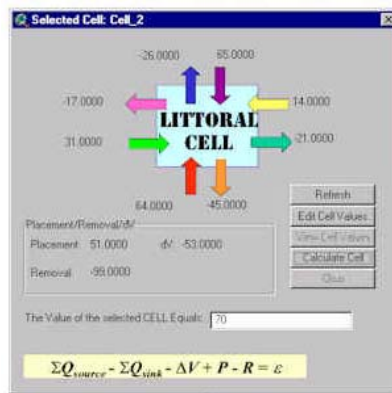


Figure 6. Sediment budgets can be calculated using its customized application.

A Sediment Budget Analysis System (SBAS) provides a framework for formulating, documenting, and calculating sediment budgets, including estimation of uncertainty, and hence, the reliability of the budget. SBAS tools have been specifically developed in the ArcView environment to aid GIS users in the creation of sediment budgets. Users have the ability to draw littoral cells, enter input and output values for these cells, and based on these values determine a balanced sediment budget.

In Development

GIS applications require a tremendous amount of system resources and can require a significant amount of training. Therefore, all GIS projects are currently in the process of being served online. Using the latest in GIS technology, ArcIMS, ESRI's solution to the serving dynamic maps online, users of any skill level with only an internet browser and online connection, can access GIS projects anywhere and anytime.

CONCLUSIONS

The RSM GIS provides engineers and scientists with tools to both visualize spatial data and perform engineering analyses. Data visualization improves understanding of potential sediment transport pathways. Engineering analyses provide exact quantities of change in shoreline position and sand volumes. These two pieces of information are required by RSM engineers and scientists to calibrate the numerical models upon which regional sediment management concepts depend.